

REMARKS

Claims 98-106 and 119-130 are pending in the application. Claims 126 and 127 have been amended to overcome the § 112 rejections at paragraph 4 of the Office Action. Claim 98 has been amended to more specifically describe use of ozone in a gas atmosphere or environment within the process chamber. See e.g., p. 10, lns. 9-12; p. 21, lns. 15-18; p. 25, ln. 11. Reconsideration and withdrawal of the remaining rejections are requested in view of the following remarks.

The claims all include contacting or spraying a semiconductor article or workpiece with a heated aqueous solution in combination with use of ozone, as described at pages 12-14 of the application. The claims are not directed to immersion. None of the cited references, alone or in combination, suggest contacting or spraying a semiconductor article with a heated solution while exposing the article to ozone. As explained at pages 1-4 of the application, the liquid bath/immersion cleaning techniques currently used in the semiconductor manufacturing industry require a relatively large number of steps, using a relatively large number of chemicals. As a result, they are time-consuming and they slow the manufacturing process.

Additionally, the equipment required to perform these liquid bath techniques is bulky, as various tanks are needed, and the fabrication facility must therefore provide space for the tanks. This adds to the overall processing costs. Moreover, the spent chemicals from such facilities must be appropriately disposed of in an environmentally acceptable way, further increasing the costs for cleaning semiconductor articles. It does not appear that any of the immersion prior art references discussed above have overcome these disadvantages.

The claimed steps reciting the use of ozone and heated liquid in a non-immersion method embody an important aspect not recognized in the prior art. As described in Example 1, ozone is

introduced into the process chamber along with heated liquid (at 90°C in this example). Page 29, lines 10-23. A concentration of ozone is created in the chamber, e.g., by release of bubbles of ozone gas in the liquid, by ozone gas coming out of solution in the liquid, or by direct injection or spray of ozone into the chamber. Since the solubility of ozone (like many gases) is inversely proportional to temperature, very little ozone can be dissolved into the heated liquid. (Indeed, many prior art processes using ozone rely on room temperature or chilled liquid—to increase the ozone concentration in the liquid).

Unfortunately, the reaction kinetics (or chemical cleaning action of the ozone) at room temperature or below is slower in comparison to the reaction kinetics at higher temperatures. Thus, for cleaning with ozone, on the one hand, low liquid temperatures are desired to allow for higher dissolved ozone concentrations. However, on the other hand, higher liquid temperatures are desired, to increase the reaction kinetics, and thereby reduce process times. The claimed methods harmonize these two competing parameters, as follows.

A thin boundary layer is formed on the wafer with the heated liquid, via rotation of the wafer or other suitable method. Since the liquid sprayed onto the wafer is heated, the amount of dissolved ozone in the liquid is low. However, because the liquid is in a thin layer, and because ozone is provided into the chamber, the ozone is able to diffuse through the liquid layer at a high rate, to react at the wafer surface. Since diffusion of ozone through the thin liquid layer is the primary reaction mechanism (as opposed to dissolution of ozone in the liquid), the advantages of using heated liquid (faster reaction times) are achieved, without the disadvantages (low dissolved concentrations of ozone and slower reaction times).

Turning to the § 103 rejections at paragraph 6 of the Office Action, with respect to the claimed heated solution and ozone elements, the cited prior art falls into either the immersion

tank processing category or the spin-processing category. Fukazawa '940, Otsuka JP H03-208900, and Wada JP 62-117330 are in the immersion category. Specifically, Otsuka et al. and Wada et al. teach bubbling an oxidizing gas onto a wafer immersed in a liquid bath. Otsuka describes immersion in a solution having a maximum temperature of 80° C, optionally including ozone gas bubbles (Translation p. 9). Wada et al. describes a cleaning liquid bath at up to 140° C, with ozone bubbling up to an immersed wafer. Fukazawa et al. teaches placing a wafer into a cleaning vessel that is filled with overflowing deionized water (abstract; col. 2, lines 42-45). Fukazawa is silent on temperature.

Hence, among these immersion prior art references (which may also disclose use of ozone, dissolved or bubbled into the immersion bath), the suggestion to use heat, or to not use heat, is ambiguous at best. Clearly these references do not reasonably suggest use of heated liquid and ozone in a non-immersion liquid application or spray, as claimed. These references do not suggest spraying, as recited in claims 101, 122 and 127, or rotating, as recited in claims 98 and 128, because they teach only immersion, and spraying and rotating are not feasible in immersion processing. Thus, the combination of Fukazawa with either Otsuka or Wada does not yield any of the claimed methods, as all of these references are directed to immersion processing.

Ohmi et al. is in the spin-processing category. As noted by the Examiner, Ohmi et al. does not teach the use of a heated liquid, as recited in each of the claims. Furthermore, there is no suggestion to combine the teachings of Ohmi et al., which teaches a spin-processing technique, with the teachings of any reference that teaches an immersion technique (e.g., all of the other cited references). This is because very different considerations must be taken for spin-processing methods than for immersion methods, as explained above and throughout the application.

In fact, Ohmi et al. specifically teaches away from using an immersion technique, and describes spin-processing, or "rotary cleaning," as an improvement over immersion, or "soaking," methods. For example, Ohmi et al. states that "the improvement of cleanliness is limited in the cleaning by soaking method and therefore [the inventor] attempted rotary cleaning" (col. 3, lines 60-62). Additionally, Ohmi maintains that the rotary cleaning method can achieve in 30 seconds what it takes 60 minutes to achieve in the soaking (i.e., immersion) method (col. 4, lines 50-55). Thus, Ohmi et al. clearly teaches away from employing an immersion, or "soaking," technique. Accordingly, it is improper to combine the teachings of a spin-processing reference, such as Ohmi et al., with those of an immersion reference, and therefore, no combination of the cited references is proper to yield the claimed methods.

Ohmi et al. further does not recognize the improved cleaning results achieved by diffusing ozone through a liquid boundary layer on the surface of a wafer, as described above. Accordingly, there is no suggestion in Ohmi et al. to employ heating of an aqueous solution, as claimed, to increase diffusion reaction rates.

In view of the foregoing, it is submitted that the claims are in condition for allowance, and a Notice of Allowance is requested.

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CLAIM SHEET MARKED UP TO SHOW CHANGES MADE

98. A method for cleaning a semiconductor wafer comprising:
- (a) rotating a wafer in a processing chamber;
 - (b) contacting a surface of the wafer with a heated aqueous solution and simultaneously providing ozone gas into a gas/vapor atmosphere within the processing chamber in an amount sufficient to create an oxidizing effect on the surface of the wafer to oxidize contaminants thereon; and
 - (c) removing oxidized contaminants from the surface thereof.

126. (Amended) The method of claim 122 wherein the organic material comprises a [coating of] photoresist.

127. (Amended) A method for cleaning an organic [coating] material off of a surface of a semiconductor article comprising:

- placing the article into a processing chamber;
 - spraying the surface of the article with a heated aqueous solution, while simultaneously contacting the surface of the article with ozone in an amount sufficient to oxidize the organic [coating] material;
 - removing the oxidized organic [coating] material from the surface of the article;
- and
- removing the article from the processing chamber without performing a separate rinsing step.

immersion
✓
121
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NO
SP. 121